1878MNRAS..38..348A

Photography at the Least Refrangible End of the Solar Spectrum.

By Capt. Abney, R.E., F.R.S.

Nearly two years ago I had the honour of reading a preliminary note on photographing the least refrangible end of the spectrum, and it seems that the time has come when I ought to redeem the promise implied by a "preliminary note" and enter further into the subject. Last year, owing to a change in residence, I was unable to pursue the subject with any degree of activity, but during this last winter and the present spring I have made fair progress in my researches, the results of which I lay before the meeting. These results are principally photographs themselves, and the first to which I shall call attention is one taken through three prisms of dense flint glass, each of which had a vertical angle of 62°. They were placed at the angle of minimum deviation of B and kept so. The focal lengths of the collimator and camera were 18 inches and 2 feet respectively, and a condensing lens of 6 feet focus was employed to collect the light, the middle of the collimating lens alone being filled with solar rays. In front of the slit was placed a plate of orange glass, in order to cut off the suffused blue rays, which experience had previously taught me were inimical to the production of good negatives, owing to the light dispersed in the prisms themselves. It will be noticed to what an enormous distance below A the impressions of the bands in the ultra red are to be found. If the wave lengths be used as abscissæ and the measured distances of the known lines be used as ordinates, it will be found, if the waves be completed by hand, that a wave length of not less than 10,400 tenth metres is impressed. Roughly speaking, A is 7,600 tenth metres and D 5,900 tenth metres, by which it will be seen that I was within the mark when I announced that I had obtained photographs as much below A as D was above it. Now this negative, though interesting as a feat in photography, has no practical scientific value, as the ultra red is so tremendously compressed that the absolute wave lengths could not be obtained from it.

About the time I read my last paper, Captain Tupman kindly lent me a speculum metal grating, by Rutherford, having about 8,600 lines to the inch; but it was only lately, after removing its glass covering, that I was fully able to appreciate its value. In all gratings the red, or rather the ultra red, of the first order is overlapped by the ultra violet and violet of the second order, and the higher the order the more overlap there is. To remedy this, which was a defect for the purpose for which I required it, I placed before the slit of the collimator red glass, which completely cut off the yellow and only allowed a little of the green to pass. The prisms were replaced by the grating, and a photograph of the second order of the spectrum was taken by it. Theoretically speaking, the time necessary for taking a photograph of the first order is $\frac{1}{8}$ that for taking one of the second, and $\frac{1}{27}$ for that of the third. Practically, this is not quite true, for reasons which it is

1878MNRAS..38..348A

unnecessary to enter into here. This induced me to think that if I could get a grating with double the number of lines to the inch, its first order should give me the same dispersion as the second order of the grating I was using, and at the same time the exposure ought to be more than halved. Mr. Lockyer kindly lent me such a grating, and the third photograph was taken by it. You will see that it gives the lines from C to A almost perfectly. A positive copy of this photograph I sent to Professor Piazzi Smyth, as he drew the map of this region of the spectrum which he published in the last volume of the *Edinburgh Astronomical Observations*; and I cannot do better than quote his words regarding the accuracy of the photograph :—" As the size of the glasses approximated closely to my standard camera size, 2·25 inches × 4·25 inches, I was able at once to view them with any magnifying power in a compound microscope long since arranged for such things, and the effect was astounding. I almost thought I was back again in Lisbon, viewing the Sun's spectrum itself as I used to see it."

This acknowledgment of the value of the photograph was particularly gratifying, as it came from an astronomer who had paid particular attention to this particular part of the spectrum.

The next plate shows the region of the ultra red as taken with the same grating. The most conspicuous group has a wave length of about 8,400 tenth metres and the extreme line visible has a wave length of about 9,200 tenth metres. At this point the closer ruled grating seemed to fail me, and I could not get beyond this point. It then struck me that the glass on which the lines were ruled might absorb the rays beyond (for I must explain that this grating was ruled on glass and silvered at the back) or that the red glass might absorb them. I then reverted to the first grating and adopted a different method of proceeding.

This was Fraunhofer's method, to which I was practically new—though I believe I have been credited (though inaccurately) with using it for other experiments—and after various attempts the following is an outline of the arrangement adopted. The slit was placed horizontally, a prism of 60° occupied a position at the end of the collimator next the lens, the reflection grating then received the rays and reflected them into the camera lens, the camera being tilted at an angle to make them fall on the sensitive plate. To show what sort of effect can be got I exhibit a photograph in which from the first to the fourth order of spectra were impressed on the same plate in a small camera. When this method was applied to the larger apparatus I got further into the ultra red than I had done before, and such a plate you see before you; the wave length of the last line of my group of lines visible on the plate is about 10,300 tenth metres. From indications on other plates I am inclined to think that we may get as far as 12,000 tenth metres, which it will be admitted is a tolerable distance to travel along the

1878MNRAS..38..348A

invisible spectrum. In these ultra regions the lines are faint, but perfectly measurable under a moderate magnifying power, and I have therefore proposed to myself to make a map of the ultra red. For the purpose I propose to use the overlapping of the higher order of the spectrum over that used. By cutting off the red in one case and using half the length of the slit for one exposure, and then by cutting off the blue and using the remaining half of the slit for the other, we shall have one spectrum over the other. The wave lengths of the most refrangible rays are known, and since the dispersion of the higher order is double the one below it, the wave lengths of the latter can be accurately ascertained. When once a scale is obtained the greatest difficulty will have vanished.

Now as to the process. My object has been to weight the molecules of silver bromide that they may absorb the red rays. With ordinary silver bromide the film allows these very rays to pass through whilst a blue absorption takes place. In other words, my endeavour has been to find a heavier molecule of a sensitive salt, which shall answer to the swing of the waves of the red and ultra red rays. This I first accomplished, as I stated at the time, by adding resins to the silver salt and forming what I may call a bromo-resinate of silver. But I am happy to say that I have secured the same end by, I believe, doubling the molecule of the silver bromide. Now this doubling the molecule is a matter of manipulation more than of chemical knowledge, and I might describe the process in detail, as I have already done in papers I have published, and yet the double molecule would not be obtained unless careful manipulation was attended to—manipulation easy to follow when seen, but difficult to follow from any description. I should therefore prefer to teach practically anyone who is acquainted with silver bromide emulsion making, rather than allow him to be misled by what must be imperfect directions.

I exhibit two films, both prepared with sensitive emulsion, which is composed of exactly similar ingredients, viz. pure silver bromide. You will at once note the difference in colour of the light transmitted. The one which is sensitive to the red and ultra red is of a blue tint; the other is orange. You will see that the blue tint would appear to be due to a physical arrangement of the molecules, for if a part of the film be rubbed you will see that it changes to a ruddy tint, passing through an emerald green stage. We have it so on the screen. Whether it be right or wrong in regard to other matter, I am convinced that in silver bromide we have the possible existence of two sizes of molecules. In the blue film we have the presence of both; when only the larger size is present we shall have a compound which is very much more sensitive to the lower end of the spectrum than it is to the upper. Allow me to say that these views are not original except in so far as they are applied to this subject. Whether they are correct or not, they have formed a good working hypothesis which has led me to the results obtained.

1878MNRAS..38..351G

Before closing I must refer to the comparative lengths of exposure required for these photographs. My impression is that at A the exposure required is about 25 times that required for G, in a fairly bright sun at midday; for the ultra red, as far as I have gone, I should say about 35 times. These are only approximations, but still will enable you to form some idea of the sensitiveness. I show you a photograph taken about 4 P.M. on March 18. The exposure was about 50 seconds. You will see that the red end is as strong as the blue, with the yellow much lacking in density. In other words, the yellow rays are nearly inactive.

The photograph which I showed you of the four orders of the spectrum was taken on April 3, at 2.30. It had an exposure of one minute and a half. The photograph in which the furthest band of lines was seen had an exposure of 12 minutes on the 8th, at 2.30. The slit was in this case closed as nearly as possible.

In conclusion, I have to remark that in a short time I hope to reduce the exposures considerably. In the course of some investigations, the results of which have just been communicated to the Royal Society, I found that the red rays could oxidise a photographic image as well as form it, and that in an oxidised state it was unable to be developed. If the tendency of the sensitive compound to become oxidised exceeded its tendency to become reduced, no image could be developed. By exposing *in vacuo* or in a nitrogen atmosphere I hope to eliminate altogether this oxidising effect, and so get firmer images.

I trust that this paper may be considered as the fulfilment of the promise implied in my preliminary note.

On the Duration of Meteor Showers. By R. P. Greg, Esq.

In the No. of the *Monthly Notices* of the Society for January 1878, Mr. Denning has a paper on "Suspected Secondary or Repetitive Outbursts from Radiant-points; and on the long Duration of Meteor Showers"; and Captain Tupman has appended some valuable remarks on Mr. Denning's paper.

1. In the case of a *second* outburst of the same supposed meteoric radiant, some two, three, or even four months after the first (supposing it to be a true case of double intersection of the same meteor orbit, say near its perihelion), then I imagine it could easily be shown that the apparent positions of the radiant, on each occasion, must necessarily lie at least in different quarters of the heavens; and it would be an almost impossible matter to decide whether the two radiants belonged to one and the same shower and orbit; unless indeed the individual meteors were wonderfully characteristic and similar in appearance.

2. With respect to the *duration* of meteor showers, though I